Cluster of Excellence Precision Physics, Fundamental Interactions and Structure of Matter
PRISMA

Mainz Institute for Theoretical Physics

Women at the Intersection of Mathematics and High Energy Physics

Organized by Gabriele Honecker (JGU Mainz), Sylvie Paycha (Univ. Potsdam), Kasia Rejzner (Univ. of York) and Katrin Wendland (Univ. Freiburg).

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This workshop brought together mathematicians and theoretical physicists working at the forefront of research in areas of mathematical physics which share analytic, algebraic geometric and number theoretic methods as underlying common features. The workshop focused on applications of these methods in the context of quantum field theory, quantum gravity and string theory.

The program was centered broadly around the concepts of (i) locality and observables, (ii) symmetry and duality, (iii) string compactifications, (iv) numbers and singularities. The program consisted of 90 minute introductory talks on Monday to Thursday mornings and 45 minute research talks in the afternoons and on Friday morning. This schedule allowed for ample time for free discussions. The character of the workshop was interdisciplinary. This is not only reflected by the diverse list of external participants but also by the fact that local mathematicians and theoretical physicists attended the event.

A public outreach event was organized on the International Women's Day, Wednesday 8 March 2017, where Anda Degeratu (Freiburg and Stuttgart) gave a public evening lecture about gravitational waves.

Beyond its ambitious scientific goals, the concept of the topical workshop aimed to support women, who are currently only represented by a very small fraction of researchers in the field. To achieve this goal, world-leading women in their respective fields where chosen as speakers.

Anne Taormina (Durham) opened the MITP topical workshop with a pedagogical review on string theory as a unified theory of all fundamental interactions and the challenges posed on the compactification of six extra space-like dimensions to match four-dimensional gauge and gravity theories. Xenia de la Ossa (Oxford) reviewed the mathematics of particular compactifications of heterotic string theories and discussed open issues in the description of vector bundles and moduli spaces. The shorter research talks by Mariana Grana (Saclay) and Michela Petrini (LPTHE Paris) addressed open questions that arise when generic closed string background fluxes are included. Thus, the six compact dimensions do not constitute a Calabi-Yau variety but have to be described by the mathematical framework of generalized geometry or - for sufficiently simple backgrounds - by means of double field theory. The research talk by Magdalena Larfors (Uppsala) further discussed the mathematical issues that arise when the compact space

is enhanced by one dimension to form a G_2 manifold. This can be used to describe the flow between different geometries with SU(3) structure. The application of geometric descriptions of Calabi-Yau varieties of complex dimension four was discussed in the research talks by Antonella Grassi (U. Penn) and Mirjam Cvetic (U. Penn) in the context of the so-called F-theory which interpolates between Type-IIB string theory at strong string coupling and the heterotic $E_8 \times E_8$ string theory. While Antonella Grassi focused on ongoing research in algebraic geometry and on topology features, in particular the structure of singularities which determine the four-dimensional gauge theory, Mirjam Cvetic focused on the relation of the geometry to discrete gauge symmetries.

The review talk by Johanna Knapp (TU Vienna) focused on newly emerging complementary techniques to describe string compactifications by means of gauged linear sigma models on the string worldsheet**,** which allow to compute quantum corrections to the four-dimensional effective field theory. The discussion of supersymmetric field theories was picked up by Marialuisa Frau (Turin), who presented new techniques of resummation for all the instanton contributions that are not treatable with other techniques in four dimensions

Valentina Forini (HU Berlin) extended the discussion of sigma model techniques and dualities to extract finite coupling information, which is of great interest in the context of the AdS/CFT correspondence, and she confronted analytical extrapolations with numerical results from lattice field theory. Also related to the study of dualities was Mara Ungureanu's (HU Berlin) research talk, in which she described a classical enumerative problem, the Jonquiere count of certain prescribed hyperplane tangency conditions to a smooth curve embedded in projective space, and related it to certain ergodic dynamical systems, thereby making the connection between enumerative geometry and cohomological field theory.

A series of talks dealt with singularities in quantum field theory. A way to circumvent infrared singularities is to work on a discrete space-time where the path integral becomes finite-dimensional. In her introductory talk, Catherine Meusburger (Erlangen-Nürnberg) explained how the concept of a lattice gauge theory with values in a group can be generalized to a gauge theory with values in a Hopf algebra on a graph embedded into a surface. She set up a relation between Kitaevs lattice model – a special case of the older and more general combinatorial models – for a finite-dimensional semi-simple Hopf algebra and the combinatorial quantization of Chern-Simons theory for its Drinfeld double. Singularities can simplify computations, as exemplified in an introductory talk by Ruth Britto (Dublin &CEA Saclay) on scattering amplitudes. Britto presented the physical context in which amplitude calculations are required, with a focus on singularities and discontinuities as key tools for exploration and computation.

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Singularities are inherent to Feynman integrals, one of the most important tools of perturbation theory for high precision calculations in particle physics. Feynman graphs are the point where singularities and numbers meet, since intriguing numbers arise from Feynman graphs. Luise Adams (JGU Mainz) addressed the question as to what type of functions appears in the Laurent expansion of regularized Feynman integrals and showed that the constant term of one-loop integrals involves the logarithm and the dilogarithm. Similarly, many multi-loop integrals can be expressed in terms of generalizations of the logarithm and the dilogarithm - the so-called multiple polylogarithms. However, Adams also showed how the multiple polylogarithms can be generalized to express the constant term in the Laurent expansion of some Feynman integrals such as the sunrise integral. Number patterns in Feynman graphs were the topic of Karen Yeats' (Simon Fraser University, Burnaby) talk. He presented an introduction to periods of Feynman graphs, showing their relevance for both mathematics and physics. Motives and graphs were the subject of Susama Agarwala's (U. S. Naval Academy, Annapolis) talk in which she gave a different graphical representation (unrelated to Feynman diagrams) for the numbers that arise as amplitude calculations in quantum field theories (QFTs), i.e. mixed Tate motives. Daniela Cadamuro (Göttingen) talked about locality of observables. She presented a pedagogical introduction into mathematically rigorous treatments of QFT. She started with Wightman axioms and then moved on to Haag-Kastler axioms and to the presentation of new developments in algebraic quantum field theory. Kristina Giesel (Erlangen-Nürnberg) gave an overview talk on loop quantum gravity and pointed out conceptual difficulties with the notion of observables in quantum gravity.

The topical workshop was a great success, as can be seen from the impressive scientific quality of the talks, covering a broad choice of topics. The talks were followed by lively discussions where scientific ideas were exchanged and further developed. The speakers and participants represented a cross section of scientists including experienced and established researchers, postdoctoral fellows and advanced graduate students. This created a friendly and stimulating atmosphere, which was appreciated by the participants.